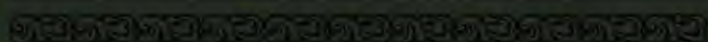


BULLETIN No. 1



Concrete Building Blocks

By S. B. NEWBERRY



ASSOCIATION OF AMERICAN
PORTLAND CEMENT MANUFACTURERS
PHILADELPHIA, PA.

Digitized by



**ASSOCIATION
FOR
PRESERVATION
TECHNOLOGY,
INTERNATIONAL**
www.apti.org

**BUILDING
TECHNOLOGY
HERITAGE
LIBRARY**

<https://archive.org/details/buildingtechnologyheritagelibrary>

From the collection of:

Alan O'Bright

CONCRETE
BUILDING BLOCKS



BY
S. B. NEWBERRY



ASSOCIATION OF AMERICAN PORTLAND
CEMENT MANUFACTURERS

TABLE OF CONTENTS.

History	3
Definition of Concrete	4
Materials for Concrete Building Blocks	6
(a) Sand and Gravel.	
(b) Stone Screenings.	
(c) Cinders.	
(d) Lime.	
(e) Cement.	
Proportions	7
(a) Strength.	
(b) Permeability.	
(c) Cost.	
Mixing	10
Systems of Concrete Construction	11
(a) Solid or Monolithic Walls.	
(b) Concrete Block Systems.	
(1) Tamped Blocks from Semi-Wet Mixture.	
(2) Block Machines.	
(3) Blocks Poured from Wet Concrete.	
(4) Tamping of Concrete Blocks.	
(5) Hardening and Storage.	
(6) Efflorescence.	
Properties of Concrete Blocks	19
(a) Strength.	
Waterproof Qualities	21
(a) Use of Properly Graded Materials.	
(b) Use of Rich Mixtures.	
(c) Use of a Facing.	
(d) Use of an Impervious Partition.	
(e) Use of Waterproof Compounds.	
(f) Application to Surface after Erecting.	
(g) General Hints of Waterproofing Qualities.	
Cost	25
Appearance and Use	26
City Specifications for Concrete Blocks	30
List of Papers Printed by the Association	32

CONCRETE BUILDING BLOCKS.

By S. B. NEWBERRY.

In the industrial progress of this country there is no feature more remarkable and striking than the development which has taken place in the applications of Portland cement. Fifteen years ago the amount of Portland cement used for all purposes in the United States was about $2\frac{1}{2}$ million barrels, of which four-fifths was imported from Europe. In 1905 the consumption exceeded 30 million barrels, a twelve-fold increase, and practically the whole of this is of American manufacture. The first and greatest victory won by the new material was its substitution for block stone in masonry constructions, such as piers, abutments and foundations, and for flagstones in the laying of sidewalks. Then followed a multitude of lesser uses, such as sewer-pipe, tiles, fence-posts, curb and gutter, piles, and ornamental architectural work of every description. Reinforced with steel rods, cement concrete has come rapidly into use in the construction of complete buildings and bridges.

Having gained full recognition as a building material of the first rank in engineering and monumental architecture, Portland cement is now invading the field of dwelling construction. All but the more costly dwellings have, until recently, been built of wood, a material that has only the qualities of cheapness and convenience to recommend it, since frame structures are admittedly perishable, uncomfortable, and unsafe against fire. Lately, however, wood has lost even the quality of cheapness, and owing to the exhaustion of our forests has advanced fully fifty per cent. in price. This has been a great hardship to home-seekers, and has forced builders to look for some other material for dwelling construction. Happily, Portland cement comes to the front, as usual, to fill the want. The hollow concrete building block, *properly made and used*, forms an ideal material for the exterior walls of buildings, and this replaces the part which, in wood, most rapidly deteriorates from exposure to weather. Buildings constructed of hollow concrete blocks are no higher in first cost than those built of frame, and are

less expensive in repairs. They have all the advantages of stone and brick in point of comfort, coolness in summer and warmth in winter, and in respect of beauty may at small cost be made fully equal to those of any other material.

Unfortunately, owing to poor workmanship and lack of artistic design, a large part of the hollow block buildings hitherto erected have fallen far short of the excellence above described. A multitude of men without capital and inexperienced in the use of cement have embarked in the business of block making, attracted by the glowing prospects of profits held out by the army of block machine agents. As a result, great quantities of inferior blocks, weak, porous and unsound, have been and are being turned out, and have been erected by careless and unskilled builders into defective and ugly structures. This state of affairs is an injury to competent and conscientious block manufacturers, and an obstacle to the adoption of a most excellent and promising building material. Blocks of first-rate quality can easily and cheaply be made, with small outlay for machinery, provided certain simple rules are intelligently followed. It is the purpose of this paper to state briefly the causes of faults in concrete blocks, and the precautions by which good and reliable work may be assured.

CONCRETE.

Concrete is an artificial stone consisting of coarse and fine fragments, such as sand, gravel and broken stone, united by cement to a solid mass.

The strength of concrete depends greatly upon its density, and this is secured by using coarse material which contains the smallest amount of voids or empty spaces. Different kinds of sand, gravel and stone vary greatly in the amount of voids they contain, and by judiciously mixing coarse and fine material the voids may be much reduced and the density increased. The density and percentage of voids in concrete material may be determined by filling a box of one cubic foot capacity and weighing it. One cubic foot of solid quartz or limestone, entirely free from voids, would weigh 165 lbs., and the amount by which a cubic foot of any loose material falls short of this weight represents the proportion of voids contained in it. For example, if a cubic foot of sand weighs 115½ lbs., the voids would be $49\frac{1}{2}-165$ ths of the total volume, or 30 per cent.

The following table gives the per cent. of voids and weight per cubic foot of common concrete materials:

	<i>% Voids.</i>	<i>Wt. per cu. ft.</i>
Sandusky Bay sand.....	32.3	111.7 lbs.
Same through 20-mesh screen.....	38.5	101.5 "
Gravel, $\frac{1}{4}$ to $\frac{1}{8}$ inch.....	42.4	95.0 "
Broken limestone, egg-size.....	47.0	87.4 "
Limestone screenings, dust to $\frac{1}{2}$ inch	26.0	122.2 "

It will be noted that screening the sand through a 20-mesh sieve, and thus taking out the coarse grains, considerably increased the voids and reduced the weight; thus decidedly injuring the sand for making concrete.

The following figures show how weight can be increased and voids reduced by mixing fine and coarse material:

	<i>% Voids.</i>	<i>Wt. per cu. ft.</i>
Pebbles, about 1 inch.....	38.7	101.2 lbs.
Sand, 30 to 40 mesh.....	35.9	105.8 "
Pebbles plus 38.7% sand, by vol....	19.2	133.5 "

Experiments have shown that the strength of concrete increases greatly with its density; in fact, a slight increase in weight per cubic foot adds very decidedly to the strength.

The gain in strength obtained by adding coarse material to mixtures of cement and sand is shown in the following table of results of experiments made in Germany by R. Dykerhoff. The blocks tested were $2\frac{1}{2}$ -inch cubes, 1 day in air and 27 days in water:

<i>Proportions by measure.</i>			<i>Per cent. cement. by volume.</i>	<i>Compression strength lbs per sq. in.</i>
<i>Cement.</i>	<i>Sand.</i>	<i>Gravel.</i>		
1	2	—	33	2,125
1	2	5	12.5	2,387
1	3	—	25	1,383
1	3	$6\frac{1}{2}$	9.5	1,515
1	4	—	20	1,053
1	4	$8\frac{1}{2}$	7.4	1,204

These figures show how greatly the strength is improved by adding coarse material, even though the proportion of cement is thereby reduced. A mixture of 1 to $12\frac{1}{2}$ of properly proportioned sand and gravel is, in fact, stronger than 1 to 4, and nearly as strong as 1 to 3, of cement and sand only.

In selecting materials for concrete, those should be chosen which give the greatest density. If it is practicable to mix two materials, as sand and gravel, the proportion which gives the greatest density should be determined by experiment, and rigidly adhered to in making concrete, whatever proportion of cement it is decided to use. Well proportioned dry sand and gravel or sand and broken stone, well shaken down, should weigh at least 125 lbs. per cubic foot. Limestone screenings, owing to minute pores in the stone itself are somewhat lighter, though giving equally strong concrete. They should weigh at least 120 lbs. per cubic foot. If the weight is less, there is probably too much fine dust in the mixture.

The density and strength of concrete are also greatly improved by use of a liberal amount of water. Enough water must be used to make the concrete thoroughly soft and plastic, so as to quake strongly when rammed. If mixed too dry it will never harden properly, and will be light, porous and crumbling.

Thorough mixing of concrete materials is essential, to increase the density and give the cement used a chance to produce its full strength. The cement, sand and gravel should be intimately mixed, dry, then the water added and the mixing continued. If stone or coarse gravel is added, this should be well wetted and thoroughly mixed with the mortar.

MATERIALS FOR CONCRETE BUILDING BLOCKS.

In the making of building blocks the spaces to be filled with concrete are generally too narrow to permit the use of very coarse material, and the block-maker is limited to gravel or stone not exceeding $\frac{1}{2}$ or $\frac{3}{4}$ inch in size. A considerable proportion of coarse material is, however, just as necessary as in other kinds of concrete work, and gravel or screenings should be chosen which will give the greatest possible density. For good results, at least one-third of the material, by weight, should be coarser than $\frac{1}{8}$ inch. Blocks made from such gravel or screenings, 1 to 5, will be found as good as 1 to 3 with sand only. It is a mistake to suppose that the coarse fragments will show on the surface; if the mixing is thorough this will not be the case. A moderate degree of roughness or variety in the surface of the blocks is, in fact, desirable, and would go far to overcome the prejudice which many architects hold against the smooth, lifeless surface of cement work.

SAND AND GRAVEL are, in most cases, the cheapest material to use for block work. The presence of a few per cent. of clay or loam is not harmful provided the mixing is thorough.

STONE SCREENINGS, if of good quality, give fully as strong concrete as sand and gravel, and usually yield blocks of somewhat lighter color. Screenings from soft stone should be avoided, also such as contain too much dust. This can be determined from the weight per cubic foot, and by a sifting test. If more than two-thirds pass $\frac{1}{8}$ -inch, and the weight (well jarred down) is less than 120 lbs., the material is not the best.

CINDERS are sometimes used for block work; they vary greatly in quality, but if clean and of medium coarseness will give fair results. Cinder concrete never develops great strength, owing to the porous character and crushability of the cinders themselves. Cinder blocks may, however, be strong enough for many purposes, and suitable for work in which great strength is not required.

LIME.—It is well known that slaked lime is a valuable addition to cement mortar, especially for use in air. In sand mixture, 1 to 4 or 1 to 5, at least one-third of the cement may be replaced by slaked lime without loss of strength. The most convenient form of lime for use in block-making is the dry-slaked or hydrate lime, now a common article of commerce. This is, however, about as expensive as Portland cement, and there is no great saving in its use. Added to block concrete, in the proportion of $\frac{1}{4}$ to $\frac{1}{2}$ the cement used, it will be found to make the blocks lighter in color, denser, and decidedly less permeable by water.

CEMENT.—Portland cement to-day, is the only hydraulic material to be seriously considered by the block-maker, and at present prices there is nothing gained by attempting the use of any of the cheaper substitutes. Natural and slag cements and hydraulic lime are useful for work which remains constantly wet, but greatly inferior in strength and durability when exposed to dry air. A further advantage of Portland cement is the promptness with which it hardens and develops its full strength; this quality alone is sufficient to put all other cements out of consideration for block work.

PROPORTIONS.

There are three important considerations which must be kept in view in adjusting the proportions of materials for block concrete—strength, permeability and cost.

So far as strength goes, it may easily be shown that concretes very poor in cement, as 1 to 8 or 1 to 10, will have a crushing resistance far beyond any load that they may be called upon to sustain. Such concretes are, however, extremely porous, and absorb water like a sponge. It is necessary, also, that the blocks shall bear a certain amount of rough handling at the factory and while being carted to work and set up in the wall, and safety in this respect calls for a much greater degree of hardness than would be needed to bear the weight of the building. Again, strength and hardness, with a given proportion of cement, depend greatly on the character of the other materials used; blocks made of cement and sand, 1 to 3, will not be so strong or so impermeable to water as those made from a good mixed sand and gravel, 1 to 5. On the whole, it is doubtful whether blocks of satisfactory quality can be made, by hand mixing and tamping, under ordinary factory conditions, from a poorer mixture than 1 to 5. Even this proportion requires for good results the use of properly graded sand and gravel or screenings, a liberal amount of water, and thorough mixing and tamping. When suitable gravel is not obtainable, and coarse mixed sand only is used, the proportion should not be less than 1 to 4. Fine sand alone is a very bad material, and good blocks cannot be made from it except by the use of an amount of cement which would make the cost very high.

The mixtures above recommended, 1 to 4, and 1 to 5, will necessarily be somewhat porous, and may be decidedly so if the gravel or screenings used is not properly graded. The water-resisting qualities may be greatly improved, without loss of strength, by replacing a part of the cement by hydrate lime. This is a light, extremely fine material, and a given weight of it goes much further than the same amount of cement in filling the pores of the concrete. It has also the effect of making the wet mixture more plastic and more easily compacted by ramming, and gives the finished blocks a lighter color.

The following mixtures, then, are to be recommended for concrete blocks. By "gravel" is meant a suitable mixture of sand and gravel, or stone screenings, containing grains of all sizes, from fine to $\frac{1}{2}$ -inch:

1 to 4 Mixtures, by Weight

Cement 150, gravel 600.

Cement 125, Hyd. lime 25, gravel 600.

Cement 100, Hyd. lime 50, gravel 600.

1 to 5 Mixtures, by Weight.

Cement 120, gravel 600.

Cement 100, Hyd. lime 20, gravel 600.

PROPORTION OF WATER.—This is a matter of the utmost consequence, and has more effect on the quality of the work than is generally supposed. Blocks made from too dry concrete will always remain soft and weak, no matter how thoroughly sprinkled afterwards. On the other hand, if blocks are to be removed from the machine as soon as made, too much water will cause them to stick to the plates and sag out of shape. It is perfectly possible, however, to give the concrete enough water for maximum density and first-class hardening properties, and still to remove the blocks at once from the mould. A good proportion of coarse material allows the mixture to be made wetter without sticking or sagging. Use of plenty of water vastly improves the strength, hardness and water-proof qualities of blocks, and makes them decidedly lighter in color. The rule should be:

Use as much water as possible without causing the blocks to stick to the plates or to sag out of shape on removing from the machine.

The amount of water required to produce this result varies with the materials used, but is generally from 8 to 9 per cent. of the weight of the dry mixture. A practiced block-maker can judge closely when the right amount of water has been added, by squeezing some of the mixture in the hand. Very slight variations in proportion of water make such a marked difference in the quality and color of the blocks that the water, when the proper quantity for the materials used has been determined, should always be accurately measured out for each batch. In this way much time is saved and uncertainty avoided.

FACING.—Some block-makers put on a facing of richer and finer mixture, making the body of the block of poorer and coarser material. As will be explained later, the advantage of the practice is, in most cases, questionable, but facings may serve a good purpose in case a colored or specially water-proof surface is required.

Facings are generally made of cement and sand or fine screenings, passing a $\frac{1}{8}$ inch sieve. To get the same hardness and strength as a 1 to 5 gravel mixture, at least as rich a facing as 1 to 3 will be found necessary. Probably 1 to 2 will be found better, and if one-third the cement be replaced by hydrate lime the waterproof qualities and appearance of the blocks will be improved. A richer facing than 1 to 2 is liable to show greater shrinkage than the body of the block, and to adhere imperfectly or develop hair-cracks in consequence.

POURED WORK.—The above suggestions on the question of proportions of cement, sand and gravel for tamped blocks apply equally to concrete made very wet, poured into the mould, and allowed to harden a day or longer before removing. Castings in a sand mould are made by the use of liquid concrete; sand and gravel settle out too rapidly from such thin mixtures, and rather fine limestone screenings are generally used.

MIXING.

To get the full benefit of the cement used it is necessary that all the materials shall be very thoroughly mixed together. The strength of the blocks as a whole will be only as great as that of its weakest part, and it is the height of folly, after putting in a liberal measure of cement, to so slight the mixing as to get no better result than half as much cement, properly mixed, would have given. The poor, shoddy and crumbly blocks turned out by many small-scale makers owe their faults chiefly to careless mixing and use of too little water, rather than to too small proportion of cement.

The materials should be mixed, dry, until the cement is uniformly distributed and perfectly mingled with the sand and gravel or screenings; then the water is to be added and the mixing continued until all parts of the mass are equally moist and every particle is coated with the cement paste.

CONCRETE MIXERS.—Hand-mixing is always imperfect, laborious and slow, and it is impossible by this method to secure the thorough stirring and kneading action which a good mixing machine gives. If a machine taking 5 or 10 horse power requires five minutes to mix one-third of a yard of concrete, it is of course absurd to expect that two men will do the same work by hand in the same time. And the machine never gets tired or shirks if not constantly urged, as it is the nature of men to do. It is hard to see how the manufacture of concrete blocks can be successfully carried

on without a concrete mixer. Even for a small business it will pay well in economy of labor and excellence of work to install such a machine, which may be driven by a small electric motor or gasoline engine. In work necessarily so exact as this, requiring perfectly uniform mixtures and use of a constant percentage of water, *batch mixers*, which take a measured quantity of material, mix it, and discharge it, at each operation, are the only satisfactory type, and continuous mixers are unsuitable. Those of the pug-mill type, consisting of an open trough with revolving paddles and bottom discharge, are positive and thorough in their action, and permit the whole operation to be watched and controlled. They should be provided with extensible arms of chilled iron, which can be lengthened as the ends become worn.

SYSTEMS OF CONCRETE CONSTRUCTION.

SOLID OR MONOLITHIC WALLS.—Foundations, walls and complete buildings of solid concrete have been erected in great numbers since the days of the Romans, and in modern times the use of reinforced or armored concrete has adapted this type of construction to a great variety of uses. In this class of work, walls, cornices, and ornamental details of buildings are moulded in place, by the use of special forms held in position by various mechanical devices. This is necessarily somewhat expensive, and requires a high degree of skill on the part of the builder; it can be successfully done only by contractors who make a specialty of the process and are provided with all necessary appliances.

CONCRETE BLOCK SYSTEMS.—For smaller and less costly buildings, *separate blocks*, made at the factory and built up into the walls in the same manner as brick or blocks of stone, are simpler, less expensive and much more rapid in construction than monolithic work. They also avoid some of the faults to which solid concrete work, unless skillfully done, is subject, such as the formation of shrinkage cracks.

There are two systems of block making, differing in the consistency of the concrete used:

1.—Blocks tamped or pressed from semi-wet concrete, and removed at once from the mould.

2.—Blocks poured or tamped from wet concrete, and allowed to remain in the mould until hardened.

TAMPED BLOCKS FROM SEMI-WET MIXTURE.—These are practically always made on a block-machine, so arranged that as soon as a block is formed the cores and side-plates are removed and the block lifted from the machine. By far the larger part of the blocks on the market are made in this way. Usually these are of the *one-piece* type, in which a single block, provided with hollow cores, makes the whole thickness of the wall. Another plan is the *two-piece* system, in which the face and back of the wall are made up of different blocks, so lapping over each other as to give a bond and hold the wall together. Blocks of the two-piece type are generally formed in a hand or hydraulic press.

Various shapes and sizes of blocks are commonly made; the builders of the most popular machines have, however, adopted the standard length of 32 inches and height of 9 inches for the full-sized block, with thickness of 8, 10 and 12 inches. Lengths of 24, 16 and 8 inches are also obtained on the same machines by the use of parting plates and suitably divided face plates; any intermediate lengths and any desired heights may be produced by simple adjustments or blocking off.

Blocks are commonly made plain, rock-faced, tool-faced, paneled, and of various ornamental patterns. New designs of face plates are constantly being added by the most progressive machine-makers. The following illustrations show some of the forms of blocks most commonly made.



BLOCKS WITH VARIOUS STYLES OF FACE.



ROCK-FACED WALL AND ORNAMENTAL CORNICE.



ROCK-FACED AND PANELED BLOCKS.



WALL OF PANELED BLOCKS

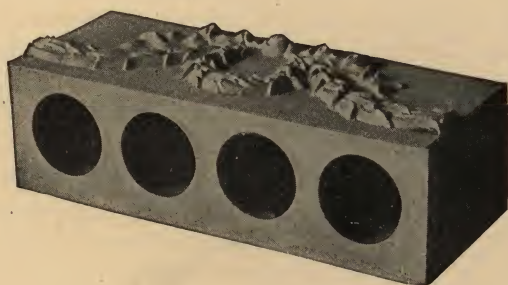


PANELED BLOCKS AND ORNAMENTAL CORNICE.

BLOCK MACHINES.—There are many good machines on the market, most of which are of the same general type, and differ only in mechanical details. They may be divided into two classes; those with vertical and those with horizontal face. In the former the face plate stands vertically, and the block is simply lifted from the machine on its base plate as soon as tamped. In the other type the face plate forms the bottom of the mould; the cores are withdrawn horizontally, and by the motion of a lever the block with its face plate is tipped up into a vertical position for removal. In case it is desired to put a facing on the blocks, machines of the horizontal-face type are considered the more convenient, though a facing may easily be put on with the vertical-face machine by the use of a parting plate.

BLOCKS POURED FROM WET CONCRETE.—As already stated, concrete made too dry is practically worthless, and an excess of water is better than a deficiency. The above-described machine process, in which blocks are tamped from damp concrete and at once removed, gives blocks of admirable hardness and quality if the maximum of water is used. A method of making blocks from very wet concrete, by the use of a large number of separable moulds of sheet steel, into which the wet concrete mixture is poured and in which the blocks are left to harden for 24 hours or longer, has come into considerable use. By this method blocks of excellent hardening and resistance to water are certainly obtained. Whether the process is the equal of the ordinary machine method in respect of economy and beauty of product must be left to the decision of those who have had actual experience with it.

The well-known cast-stone process consists in pouring liquid concrete mixture into a sand mould made from a pattern in a manner similar to that in which moulds for iron castings are produced. The sand absorbs the surplus water from the liquid mixture, and the casting is left in the mould for 24 hours or longer until thoroughly set. This process necessitates the making of a new sand mould for every casting, and is necessarily much less rapid than the machine method. It is less extensively used for building blocks than for special ornamental architectural work, sills, lintels, columns, capitals, etc., and for purposes of this kind it turns out products of the highest quality and beauty.



ORNAMENTAL ARCHITECTURAL WORK
MADE BY THE CAST STONE PROCESS

TAMPING OF CONCRETE BLOCKS.—This is generally done by means of hand-rammers. Pneumatic tampers, operated by an air-compressor, are in use at a few plants, apparently with considerable saving in time and labor and improvement in quality of work. Moulding concrete by *pressure*, either mechanical or hydraulic, is not successful unless the pressure is applied to the face of a comparatively thin layer. If compression of thick layers, especially of small width, is attempted, the materials arch and are not compacted at any considerable depth from the surface. Moulding blocks by pressure is therefore practiced only in the two-piece system, in which the load is applied to the surface of pieces of no great thickness. Hand tamping must be conscientious and thorough, or poor work will result. It is important that the mould should be filled a little at a time, tamping after each addition; at least four fillings and tappings should be given to each block. If the mixture is wet enough no noticeable layers will be formed by this process.

HARDENING AND STORAGE.—Triple decked cars to receive the blocks from the machines will be found a great saving of labor, and are essential in factories of considerable size. Blocks will generally require to be left on the plates for at least 24 hours, and must then be kept under roof, in a well-warmed room, with frequent sprinkling, for not less than five days more. They may then be piled up out of doors, and in dry weather should be wetted daily with a hose. Alternate wetting and drying is especially favorable for the hardening of cement, and concrete so treated gains much greater strength than if kept continuously in water or dry air.

Blocks should not be used in building until at least four weeks from the time they are made. During this period of seasoning, blocks will be found to shrink at least 1-16 inch in length, and if built up in a wall when freshly made, shrinkage cracks in the joints or across the blocks will surely appear.

EFFLORESCENCE, or the appearance of a white coating on the surfaces, sometimes takes place when blocks are repeatedly saturated with water and then dried out; blocks laid on the ground are more liable to show this defect. It results from diffusion of soluble sulphates of lime and alkalis to the surface. It tends to disappear in time, and rarely is sufficient in amount to cause any complaint.

PROPERTIES OF CONCRETE BLOCKS.

Strength.

In the use of concrete blocks for the walls of buildings, the stress to which they are subjected is almost entirely one of *compression*. In compressive strength well-made concrete does not differ greatly from ordinary building stone. It is difficult to find reliable records of tests of sand and gravel concrete, 1 to 4 and 1 to 5, such as is used in making blocks; the following figures show strength of concrete of approximately this richness, also the average of several samples each of well-known building stones, as stated by the authorities named:

Limestone, Bedford, Ind. (Ind. Geo. Survey) . . .	7792	lbs
“ Marblehead, Ohio, (Q. A. Gillmore) . .	7393	“
Sandstone, N. Amherst, Ohio “ . .	5831	“
Gravel Concrete, 1:1.6:2.8, at 1 yr. (Candlot) . . .	5500	“
“ “ 1:1.6:3.7, “ “ “ “ “ “ “	5050	“
Stone Concrete, 1:2:4 at 1 yr. (Boston El. R. R.) . .	3904	“

Actual tests of compression strength of hollow concrete blocks are difficult to make, because it is almost impossible to apply the load uniformly over the whole surface, and also because a block 16 inches long and 8 inches wide will bear a load of 150,000 to 200,000 lbs., or more than the capacity of any but the largest testing machines. Three one-quarter blocks, 8 inches long, 8 inches wide and 9 inches high, with hollow space equal to one-third of the surface, tested at the Case School of Science, showed strengths of 1,805, 2,000 and 1,530 lbs. per square inch, respectively, when 10 weeks old.

Two blocks 6 x 8 x 9 inches, 22 months old, showed crushing strength of 2,530 and 2,610 lbs. per sq. inch.

These blocks were made of cement $1\frac{1}{4}$, lime $\frac{1}{2}$, sand and gravel 6, and were tamped from damp mixture.

It is probably safe to assume that the minimum crushing strength of well-made blocks, 1 to 5, is 1,000 lbs. per square inch at 1 month and 2,000 lbs. at 1 year.

Now a block 12 inches wide and 24 inches long has a total surface of 288 sq. inches, or, deducting 1-3 for openings, a net area of 192 inches. Such a block, 9 inches high, weighs 130 lbs. Assuming a strength of 1,000 lbs. and a factor of safety of 5, the safe load would be 200 lbs. per sq. inch, or $200 \times 192 = 38,400$ lbs. for the whole surface of the block. Dividing this by the weight of the block

130 lbs., we find that 295 such blocks could be placed one upon another, making a total height of wall of 222 ft., and still the pressure on the lowest block would be less than one-fifth of what it would actually bear.

This shows how greatly the strength of concrete blocks exceeds any demands that are ever made upon it in ordinary building construction.

The safe load above assumed, 200 lbs., seems low enough to guard against any possible failure. In Taylor and Thompson's work on concrete a safe load of 450 lbs. for concrete 1 to 2 to 4 is recommended; this allows a factor of safety of $5\frac{1}{2}$. On the other hand, the Building Code of the City of Cleveland permits concrete to be loaded only to 150 lbs. per sq. inch, and limits the height of walls of 12-inch blocks to 44 ft. The pressure of such a wall would be only 40 lbs. per square inch; adding the weight of 2 floors at 25 lbs. per sq. ft. each, and roof with snow and wind pressure 40 lbs. per sq. ft., we find that with a span of 25 ft. the total weight on the lowest blocks would be only 52 lbs. per sq. inch. or about one-twentieth of their minimum compression strength.

Blocks with openings equal to only one-third the surface, as required in many city regulations, are heavy to handle, especially for walls 12 inches and more in thickness, and as the above figures show, are enormously stronger than there is any need of. Blocks with openings of 50 per cent. would be far more acceptable to the building trade, and if used in walls not over 44 ft. high, with floors and roof calculated as above for 25 feet span, would be loaded only to 56 lbs. per square inch of actual surface. This would give a factor of safety of 18, assuming a minimum compression strength of 1,000 lbs.

There is no doubt that blocks with one-third opening are inconveniently and unnecessarily heavy. Such a block, 32 inches long, 12 inches wide, and 9 inches high, has walls about $3\frac{1}{2}$ inches thick, and weighs 180 lbs. A block with 50 per cent. open space would have walls and partitions 2 inches in thickness, and would weigh about 130 lbs. With proper care in manufacture, especially by using as much water as possible, blocks with this thickness of walls may be made thoroughly strong, sound and durable. It is certainly better for strength and water-resisting qualities to make thin-walled blocks of rich mixture, rather than heavy block of poor and porous material.

WATER-PROOF QUALITIES.

The chief fault of concrete building blocks, as ordinarily made, is their tendency to absorb water. In this respect they are generally no worse than sandstone or common brick; it is well known that stone or brick walls are too permeable to allow plastering directly on the inside surface, and must be furred and lathed before plastering, to avoid dampness. This practice is generally followed with concrete blocks, but their use and popularity would be greatly increased if they were made sufficiently waterproof to allow plastering directly on the inside surface.

For this purpose it is not necessary that blocks should be perfectly water-proof, but only that the absorption of water shall be *slow*, so that it may penetrate only part way through the wall during a long-continued rain. Walls made entirely water-tight, are, in fact, objectionable, owing to their tendency to "sweat" from condensation of moisture on the inside surface. For health and comfort walls must be slightly porous, so that any moisture formed on the inside may be gradually absorbed and carried away.

Excessive water-absorption may be avoided in the following ways:

1.—USE OF PROPERLY GRADED MATERIALS.—It has been shown by Feret and others that porosity and permeability are two different things; porosity is the total proportion of voids or open spaces in the mass, while permeability is the rate at which water, under a given pressure, will pass through it. Permeability depends on the *size* of the openings as well as on their total amount. In two masses of the same porosity or percentage of voids, one consisting of coarse and the other of fine particles, the permeability will be greater in case of the coarse material. The least permeability, and also the least porosity, are, however, obtained by use of a suitable mixture of coarse and fine particles. Properly graded gravel or screenings, containing plenty of coarse fragments and also enough fine material to fill up the pores, will be found to give a much less permeable concrete than fine or coarse sand used alone.

2.—USE OF RICH MIXTURES.—All concretes are somewhat permeable by water under sufficient pressure. Mixtures rich in cement are of course much less permeable than poorer mixtures. If the amount of cement used is more than sufficient to fill the voids in the sand and gravel, a very dense concrete is obtained, into which the

penetration of water is extremely slow. The permeability also decreases considerably with age, owing to the gradual crystallization of the cement in the pores, so that concrete which is at first quite absorbent may become practically impermeable after exposure to weather for a few weeks or months. There appears to be a very decided increase in permeability when the cement is reduced below the amount necessary to fill the voids. For example, a good mixed sand and gravel weighing 123 lbs. per cubic foot, and therefore containing 25 per cent. voids, will give a fairly impermeable concrete in mixtures up to 1 to 4, but with less cement will be found quite absorbant. A gravel with only 20 per cent. voids would give about equally good results with a 1 to 5 mixture; such gravel is, however, rarely met with in practice. On the other hand, the best sand, mixed fine and coarse, seldom contains less than 33 per cent. voids, and concrete made from such material will prove permeable if poorer than 1 to 3.

Filling the voids with cement is a rather expensive method of securing water-proof qualities, and gives stronger concretes than are needed. The same may be accomplished more cheaply by replacing part of the cement by slaked lime, which is an extremely fine-grained material, and therefore very effective in closing pores. Hydrate lime is the most convenient material to use, but nearly as costly as Portland cement at present prices. A 1 to 4 mixture in which one-third the cement is replaced by hydrate lime will be found equal to a 1 to 3 mixture without the lime. A 1 to 4 concrete made from cement 1, hydrate lime $\frac{1}{2}$, sand and gravel 6 (by weight), will be found fairly water-tight, and much superior in this respect to one of the same richness consisting of cement $1\frac{1}{2}$, sand and gravel 6.

The cost of lime may be greatly reduced by using ordinary lump lime slaked to a paste. The lime must, however, be very thoroughly hydrated, so that no unslaked fragments may remain to make trouble by subsequent expansion. Lime paste is also very difficult to mix, and can be used successfully only in a concrete mixer of the pug-mill type. Ordinary stiff lime paste contains about 50 per cent. water; twice as much of it, by weight, should therefore be used as of dry hydrate lime.

3.—USE OF A FACING.—Penetration of water may be effectively prevented by giving the blocks a facing of richer mixture than the body. For the sake of smooth appearance, facings are generally

made of cement and fine sand, and it is often noticed that these do not harden well. It should be remembered that a 1 to 3 sand mixture is no stronger and little if any better in water absorption than a 1 to 5 mixture of well graded sand and gravel. To secure good hardness and resistance to moisture a facing as rich as 1 to 2 should be used.

4.—USE OF AN IMPERVIOUS PARTITION.—When blocks are made on a horizontal-face machine, it is a simple matter, after the face is tamped and cores pushed into place, to throw into each opening a small amount of rich and rather wet mortar, spread this fairly evenly, and then go on tamping in the ordinary mixture until the mould is filled. A dense layer across each of the cross-walls is thus obtained, which effectually prevents moisture from passing beyond it. A method of accomplishing the same result with vertical-face machines, by inserting tapered wooden blocks in the middle of the cross-walls, withdrawing these blocks after tamping and filling the spaces with rich mortar, has lately been patented by Purdy and Henderson, of New York. In the two-piece system the penetration of moisture through the wall is prevented by leaving an empty space between the web of the block and the inside face, or by filling this space with rich mortar.

5.—USE OF WATER-PROOF COMPOUNDS.—There are compounds on the market, of a fatty or waxy nature, which when mixed with cement to the amount of only one or two per cent. of its weight, increase its water-resisting qualities in a remarkable degree. By thoroughly mixing 1 to 2 lbs. of suitable compound with each sack of cement used, blocks which are practically water-proof may be made, at very small additional cost, from 1 to 4 or 1 to 5 mixtures. In purchasing water-proof compound, however, care should be taken to select such as has been proved to be *permanent* in its effect, as some of the materials used for this purpose lose their effect after a few days' exposure to weather, and are entirely worthless.

6.—APPLICATIONS TO SURFACE AFTER ERECTING. — Various washes, to make concrete and stone impervious to water, have been used with some success. Among these the best known is the Sylvester wash of alum and soap solution. It is stated that this requires frequent renewal, and it is hardly likely to prove of any value in the concrete block industry. The writer's experience has been that the most effective remedy, in case a concrete building proves damp, is to give the outside walls a *very thin* wash of cement

suspended in water. One or two coats will be found sufficient. If too thick a coating is formed it will show hair cracks. The effect of the cement wash is to make the walls appear lighter in color, and if the coating is thin the appearance is in no way injured.

GENERAL HINTS ON WATER-PROOF QUALITIES.—To obtain good water-resisting properties, the first precaution is to make the concrete *sufficiently wet*. Dry-tamped blocks, even from rich mixture, will always be porous and absorbent, while the same mixture in plastic condition will give blocks which are dense, strong, and water-tight. The difference in this respect is shown by the following tests of small concrete blocks, made by the writer. The concrete used was made of 1 part cement and 5 parts mixed fine and coarse sand, by weight.

No. 1.—With 8 per cent. water, rather dryer than ordinary block concrete, tamped in mould.

2.—With 10 per cent. water, tamped in mould, too wet to remove mould at once.

3.—With 25 per cent. water, poured into a mould resting on a flat surface of dry sand; after 1 hour the surface was troweled smooth; mould not removed until set.

These blocks were allowed to harden a week in moist air, then dried. The weights, voids, and water absorption were as follows:

	1	2	3
	<i>Damp-tamped.</i>	<i>Wet-tamped.</i>	<i>Poured.</i>
Weight per cubic foot, lb.	122.2	123.9	110.0
Voids, calculated, per cent. of volume	25.9	24.9	33.3
Water required to fill voids, per cent. of wt.	9.8	9.4	12.5
Water absorbed after 2 hours, per cent. of wt.	8.8	6.4	10.5

The rate at which these blocks absorbed water was then determined by drying them thoroughly, then placing them in a tray containing water $\frac{1}{4}$ inch in depth, and weighing them at intervals.

<i>Water absorbed</i>	1	2	3
<i>per cent. by weight.</i>	<i>Damp-tamped.</i>	<i>Wet-tamped.</i>	<i>Poured.</i>
$\frac{1}{2}$ hour	2.0	0.9	1.8
1 "	3.2	1.1	2.5

<i>Water absorbed</i>		1	2	3
<i>per cent. by weight.</i>		<i>Damp-tamped.</i>	<i>Wet-tamped.</i>	<i>Poured.</i>
2	hours	4.1	1.6	3.2
4	"	5.2	2.0	3.8
24	"	6.1	3.4	7.0
48	"	6.4	4.3	7.5

These figures show that concrete which is sufficiently wet to be thoroughly plastic absorbs water much more slowly than dryer concrete, and prove the importance of using as much water as possible in the damp-tamping process.

COST.

The success of the hollow concrete block industry depends to a great extent on cheapness of the product, since it is necessary, in order to build up a large business, to compete in price with common brick and rubble stone. At equal cost, well-made blocks are certain to be preferred, owing to their superiority in strength, convenience, accurate dimensions, and appearance. For the outside walls of handsome buildings, blocks come into competition with pressed brick and dressed stone, which are, of course, far more costly. Concrete blocks can be sold and laid up at a good profit at 25 cents per cubic foot of wall. Common red brick costs generally about 12 dollars per thousand, laid. At 24 to the cubic foot, a thousand brick are equal to 41.7 cu. ft. of wall; or, at \$12, 29c. per cu. ft. Brick walls with pressed brick facing cost from 40c. to 50c. per cubic foot, and dressed stone from \$1 to \$1.50 per foot.

The factory cost of concrete blocks varies according to the cost of materials. Let us assume cement to be \$1.50 per barrel of 380 lbs., and sand and gravel 25c. per ton. With a 1 to 4 mixture, 1 barrel cement will make 1,900 lbs. of solid concrete, or at 130 lbs. per cu. ft., 14.6 cubic feet. The cost of materials will then be

Cement, 380 lbs.....	\$1.50
Sand and gravel, 1,520 lbs.....	0.19

Total	\$1.69
-------------	--------

or 11.5c. per cu. ft. solid concrete. Now, blocks 9 inches high and 32 inches long make 2 square feet of face of wall, each. Blocks of this height and length, 8 inches thick, make 1 1-3 cubic feet of wall; and blocks 12 inches thick make 2 cubic feet of wall. From these figures we may calculate the cost of materials for these blocks, with

cores or openings equal to 1-3 or $\frac{1}{2}$ the total volume, as follows:

Per cu. ft. of block, 1-3 opening.....	7.7 cts.
Per cu. ft. of block, $\frac{1}{2}$ opening.....	5.8 "
Block 8 x 9 x 32 inches, 1-3 opening.....	10.3 "
Block 8 x 9 x 32 inches, $\frac{1}{2}$ opening.....	7.7 "
Block 12 x 9 x 32 inches, 1-3 opening.....	15.4 "
Block 12 x 9 x 32 inches, $\frac{1}{2}$ opening.....	11.6 "

If one-third of the cement is replaced by hydrate lime the quality of the blocks will be improved, and the cost of material reduced about 10 per cent.

The cost of labor required in manufacturing, handling and delivering blocks will vary with the locality and the size and equipment of factory. With hand-mixing, 3 men at average of \$1.75 each will easily make 75 8-inch or 50 12-inch blocks, with 1-3 openings, per day. The labor cost for these sizes of blocks will therefore be 7c. and 10 $\frac{1}{2}$ c. respectively. At a factory equipped with power concrete mixer and cars for transporting blocks, in which a number of machines are kept busy, the labor cost will be considerably less. An extensive industry located in a large city is, however, subject to many expenses which are avoided in a small country plant, such as high wages, management, office rent, advertising, etc., so that the total cost of production is likely to be about the same in both cases. A fair estimate of total factory cost is as follows:

	<i>Material.</i>	<i>Labor.</i>	<i>Total.</i>
8 x 32 inch, 1-3 space.....	10.3	7	17.3 cts.
8 x 32 inch, $\frac{1}{2}$ "	7.7	6	13.7 "
12 x 32 inch, 1-3 "	15.4	10.5	25.9 "
12 x 32 inch, $\frac{1}{2}$ "	11.6	9	20.6 "

With fair allowance for outside expenses and profit, 8-inch blocks may be sold at 30c. and 12-inch at 40c. each. For laying 12-inch blocks in the wall, contractors generally figure about 10c. each. Adding 5c. for teaming, the blocks will cost 55c. each, erected, or 27 $\frac{1}{2}$ c. per cubic foot of wall. This is less than the cost of common brick, and the above figures show that this price could be shaded somewhat, if necessary, to meet competition.

APPEARANCE AND USE.

Since concrete blocks are, as has been shown, more convenient, more efficient, and cheaper than any other building material, it would

naturally be expected that they would quickly take the place of wood, brick and stone and be generally adopted for all ordinary construction. The growth of the block industry has, indeed, been rapid, but it plays as yet but a small part in the building operations of the country. It is evident on all sides that concrete blocks meet with opposition and suspicion on the part of architects and builders, and in consequence are much less generally adopted than their merits appear to warrant. It is neither just nor expedient to attribute this opposition to prejudice against a new material. Rather should we try to find and remove the grounds on which such opposition is based. My observation leads me to believe that architects and engineers have no prejudice against concrete, but on the contrary welcome it as a building material by means of which they can obtain results never before within their reach. And they are also keenly watching the block industry, and are ready to adopt block construction as soon as they are offered a product which meets their ideas as to utility and beauty.

Fortunately, no material is so elastic in its capabilities as concrete, and no other can with so little effort be adapted to produce any effect desired. It is hardly to be expected that the block of the present day will be the block of the future; the type which is most economical, practical and beautiful will gradually come to the front, and that which is costly, clumsy and ugly will become a thing of the past. To make a success of the business we must keep our eyes open, watch what others are doing in the way of invention and improvement, and study the wants of customers. And we must not hesitate to throw our old block machines into the scrap heap when we are sure we have found a better apparatus and process.

The objections which architects and builders make to blocks now on the market are chiefly the following:

- Poor workmanship,
- Fixed dimensions,
- Too great weight,
- Unpleasing appearance.

As to workmanship, shoddy, weak and crumbling blocks are far too often met with. Good concrete should be hard and dense, and should give out a musical tone when struck with a hammer. If your blocks sound dead when struck, and break easily with an earthy fracture, you are either using too poor a mixture or working too dry, probably the latter. It does not pay, for the sake of low

factory cost, to turn out work of this kind. If there is any money to be made in the block business it will be made by furnishing a good article at a living price, and in no other way. Will any one argue that it pays to make rotten blocks at a factory cost of two cents less than good ones? My belief is that the tendency of the future will be toward the use of wetter concrete, and the adoption of a process which makes this possible.

As to fixed dimensions of blocks, the standard length of 32 inches, divided into halves, thirds and quarters, is very convenient, and is generally conformed to by architects, for simple work, without much objection. To be fully successful, however, and to overcome all prejudice, the block-maker must be ready to furnish any size or shape that may be called for to suit architects' designs. It would be very pleasant if we could confine ourselves to the standard size and let customers "take it or leave it." But such an attitude bars the way to any wide use of blocks in varied and attractive buildings, and cannot be maintained without loss of trade. Architects want also courses of greater or less height than the 9 inch standard, and all manner of cornices, copings, columns and capitals. This may frighten the timid and conservative block-maker, but it is in that direction that success lies, and the production of these special shapes requires only ingenuity, courage and mechanical skill. Until we can say to the architect "Design whatever you like, we'll make it for you," he will shy at us and our product. He will, of course, readily appreciate that special shapes cost more than standard, and if he knows he can get just what he wants he will be more likely to accept, so far as he can, what can be conveniently and cheaply furnished.

Preference should be given, therefore, to the machine which permits the greatest variety of sizes and shapes to be easily made. And the greatest business success is likely to come to the manufacturer who shows the least inclination to get into a rut, and is most ready to adapt his product to the wants of his patrons.

The objection to the weight of the one-piece block comes chiefly from masons and contractors. Hoisting 12 x 32 inch blocks weighing 180 lbs. to the upper floors of a building, and handling them onto the wall, is a considerable task, and it is largely on this account that the half-block of the two-piece system, 24 inches long, weighing only 64 lbs., is received with so much favor. It must be

remembered, however, that the two-piece blocks make a wall with over 50 per cent. opening, and one-piece block of the same thickness of walls—2 inches—would also be light to handle and doubtless very popular. My belief is that the one-piece block of the future will be 24 inches long and with a thickness of walls of not over 2 inches. Such a block, 12 inches wide and 9 inches high, will weigh only 97 lbs., and if well and honestly made will bear rough handling and any possible load.

Finally, it is to the *appearance* of concrete blocks, as ordinarily made and used, that architects and other persons of taste and judgment make the greatest objection. Anything that savors of imitation, that pretends to be what it is not, will always be hated and condemned by all who know the difference between the good and the bad. The common rock-faced block is an imitation of the cheapest form of quarry stone, and a poor imitation at that, for no two natural stone blocks are alike in surface; while even if you have half a dozen rock-face plates of the same size of block, and strive to shuffle up the product of these plates in the yard and on the work, you will never see a building in which here and there, blocks from the same plate are not found one above or beside the other. And it is surprising how unerringly the eye will pick out the spots where this occurs, and what a feeling of "something lacking" is awakened. It is bad art and quite indefensible. The "rock-faced galvanized iron" of our country store-fronts is a no more glaring fraud. The rock-faced block must go.

Now let us inquire what constitutes imitation, and how concrete may be made to stand on its merits and look like what it really is. In the first place, concrete must always look like stone, because it *is* stone. An artificial stone, consisting of grains of sand and gravel or limestone crystals bound together by a little Portland cement, cannot help looking like natural sandstone or limestone made up of the same materials bound together by carbonate lime or soluble silicates slowly deposited in its pores. We need never be afraid that concrete will be condemned for its stony look, since that is its nature. All we need to avoid is giving the work an appearance which is unnatural to concrete, such as the rock-face. Smooth, ribbed and paneled surfaces, also good ornamental patterns for friezes or cornices, are entirely legitimate, and equally characteristic of stone, metal, terra cotta or concrete. Forms of beauty may properly be reproduced in any material; the only thing to be avoided is

pretense—the attempt to deceive the observer into the belief that the material he sees is something different from what it really is.

The surface which best pleases the eye of artist and architect is a rough and varied one, rather than the smooth, dead look which rich cement mixtures have. The film of cement which coats the face of the work is certainly monotonous and unattractive. This can be cheaply removed by washing with very weak acid, and very beautiful effects are thus obtained, especially with crushed stone or gravels containing pebbles of various colors.

CITY SPECIFICATIONS FOR CONCRETE BLOCKS.

In order to guard against the use of blocks of poor quality and to insure safe construction of block buildings, a number of cities have adopted specifications for the acceptance and use of building blocks of concrete. The building regulations of New York City* in regard to all materials used as substitutes for brick or stone are extremely severe, requiring tests to be made on blocks the size and shape of an ordinary brick, which must show an average modulus of rupture of 450 lbs. in transverse test, average compression strength of 3,000 lbs., water absorption not over 15 per cent., loss of not more than 33 per cent. strength after freezing and thawing 20 times, and no disintegration after heating 1 hour to 1,700 degrees F. and plunging into cold water.

The City of Philadelphia* for a time followed these requirements, but has lately modified them and provides that tests of hollow concrete blocks shall be made on full-sized specimens. The most important requirements are:

Blocks to be made of Portland cement with not more than 5 parts sand and gravel or crushed rock; hollow space to be not over 33 per cent. (20 and 25 per cent. in lower parts of high walls); maximum load 111 lbs. per square inch of wall; crushing strength 1,000 lbs. per sq. inch of total surface of block including openings; absorption, freezing and fire tests as in New York requirements.

According to the Cement Age, concrete blocks in the Philadelphia market have shown compression strength of 1,200 to 1,600 lbs., absorption of about 5 per cent., little loss of strength on freezing, and have passed the fire test well.

*Cement Age, Sept. '05, p. 274.

*Cement Age, Sept. '05, p. 278.

The City of Newark, N. J., requires that blocks shall be not poorer than 1 to 4; they must be no more than 36 inches long and 10 inches high, and not less than 8 nor more than 16 inches wide; the hollow spaces must not exceed one-third; they must not be used until 30 days old, and must show a crushing strength of 1,500 lbs. per square inch.

These various city requirements seem generally reasonable and certainly abundantly severe. It is difficult to see, however, why the hollow spaces should be limited to one-third or less when strength is fully provided for by a compression requirement of 1,000 lbs. on the whole area of the block. If blocks with thinner walls will show this strength, there appears to be no ground for prohibiting them.

(Note: The cuts used in this paper were kindly loaned by The Progress Publishing Co., Ideal Concrete Machinery Co., Miracle Pressed Stone Co., and Stevens Cast Stone Co.)

Bulletins relating to the use of Portland Cement, published by the Association of American Portland Cement Manufacturers, Land Title Building, Philadelphia. Copies may be obtained upon application.

- Bulletin No. 1. "Concrete Building Blocks."
- Bulletin No. 2. "The Possibilities of Concrete Construction from the Standpoint of Utility and Art."
- Bulletin No. 3. "Sand for Mortar and Concrete."
- Bulletin No. 4. "Notes on Cement Testing."
- Bulletin No. 5. Out of print.
- Bulletin No. 6. Out of print.
- Bulletin No. 7. "The Making and Driving of Corrugated Concrete Piles."
- Bulletin No. 8. Out of print.
- Bulletin No. 9. "Methods of Testing and Some Peculiarities of Cement."
- Bulletin No. 10. "Decoration of Concrete with Colored Clays."
- Bulletin No. 11. "Cost Reduction of Reinforced Concrete Work."
- Bulletin No. 12. "The Progress and Logical Design of Reinforced Concrete."
- Bulletin No. 13. "Forms for Concrete Construction."
- Bulletin No. 14. Out of print.
- Bulletin No. 15. "Concrete Bridges."
- Bulletin No. 16. "Regulation and Control of Concrete Construction."
- Bulletin No. 17. "Hydraulic Properties of Reground Cement Mortars."
- Bulletin No. 18. "Reinforced Concrete Chimneys."
- "Standard Methods of Testing and Specifications for Cement."
- "Fireproof Qualities of Concrete Construction."
- "Results of Tests"—Made in our Laboratory during the World's Fair, St. Louis, Mo., 1904.
- "The Concrete Review"—Monthly—Yearly Subscription, 50c.
- Directory of Portland Cement Manufacturers Having Plants in Operation. Price 75c. Post Free.
- Portfolio of Competitive Designs of Concrete Houses of Moderate Cost, Price \$1.00, Post Free.



